A comparative study between Johnson formula and Hadlock formula for estimating fetal weight in term gestation

Abstract

Background: Ultrasound study forms a very important tool in present day obstetrics. The accurate assessment of weight by ultrasound examinations is mandatory for obstetric management particularly at term. **Objective:** To compare Johnson’s formula and Hadlock’s formula for estimating fetal weight in term gestation. **Materials and Methods:** We performed a prospective observational study in 200 women. The estimated fetal weight (EFW) was measured at term by sonological formula i.e. Hadlock formula \[ \text{Log10 EFW = -1.3596 - 0.00386 (AC x FL) + 0.0064 (HC) + 0.0061(BPD x AC) + 0.0425 (AC) + 0.174 (FL)} \] and Johnson’s formula \[(\text{Symphysio-fundal height (cms) - X}) * 155] and compared with the actual birth weight. The statistical analysis was done using Z test.

**Results:** The mean birth weight of Hadlock formula is closest to the mean of actual birth weight when compared to that of Johnson’s formula. P value obtained for both the formulae were <0.01, highly significant. The mean error of Hadlock formula was 188 grams and the mean error of Johnson formula was 202.148 grams. The percentile error of <20% was 77% in Hadlock formula compared to 79% in Johnson’s formula.

**Conclusion:** The mean birth weight of hadlock formula was closest to the mean of actual birth weight when compared to Johnson’s formula. The least mean error was noted in the birth weight between 2.5-3.5Kg. Johnson’s formula overestimated the weight in SGA fetuses and Hadlock formula underestimated the weight in LGA fetus.

**Keywords:** estimated fetal weight, Hadlock formula, Johnson’s formula

Introduction

Ultrasound study forms a very important tool in present day obstetrics. The accurate assessment of weight by ultrasound examinations is mandatory for obstetric management particularly at term.¹

The accurate estimation of fetal weight helps in decision making in preterm fetus, small for gestational age (SGA) fetus, fetal growth retardation (FGR), preterm premature rupture of membranes, large for gestational age (LGA) fetus, macrosomic fetus, previous caesarean sections where the time and the route of delivery needs to be planned in advance.² Thus estimating fetal weight antenatally is of utmost important to the obstetricians so that:

- a. They can have preventive measures to deal with respiratory distress syndrome (RDS), hypoglycemia in a low birth weight (LBW) neonate.
- b. Anticipate problems of shoulder dystocia in macrosomic fetus. Thus, reduce the risk of mortality and morbidity to mother and neonate.
- c. There are different methods of estimation of fetal weight at term:³-
  - a) Tactile Technique: It is the oldest method of assessment of fetal dimensions through the maternal abdomen. This is the most intuitive technique, since it involves palpating the fetal parts directly through the maternal abdominal wall to estimate fetal weight. This method is both convenient and costless, but it has long been known to possess large predictive errors especially in large infants.
  - b) Use of maternal characteristics birth weight prediction equation: This includes the application of a quantitative birth weight prediction equation that is based on maternal and pregnancy specific factors.
  - c) Other clinical methods using various formulae viz:
    - i. Using abdominal girth: Abdominal girth (cms) * symphysiofundal height (cms)
    - ii. Johnson’s formula: Fetal weight (grams)=(symphysiofundal height (cms) - X) *155
      Where, X = 13 when presenting part not engaged
      X = 12 when presenting part at 0 station
      X = 11 when presenting part at +1 station.
    - iii. Dawn’s formula: Fetal weight (grams)=Longitudinal diameter of the uterus *(Transverse diameter of uterus)² * 1.44. All the measurements are made using pelvimeter.
    - iv. Hadlock formula: \[ \text{Log10 EFW = -1.3596 - 0.00386 (AC x FL) + 0.0064 (HC) + 0.0061(BPD x AC) + 0.0425 (AC) + 0.174 (FL)} \]
    - v. Ultrasound method: The most modern and technologically
dependent method for assessing fetal weight relies on fetal measurements obtained via ultrasonography which forms a gold standard in present day obstetrics.

There are different algorithms based on combination of various ultrasound parameters like biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), anterior posterior trunk diameter (APTD), transverse trunk diameter (TTD), fetal trunk cross sectional area (FTA) which are used singly or in combinations. The different algorithms used worldwide are Hadlock formula, Shepard formula, Tokyo University formula, Osaka University formula, Campbell, Hansman, Sabbagha, Warsof Aoki, etc. Among the standard formulae stored in most ultrasound machines which formula is most useful to estimate birth weight to near accuracy to actual birth weight for our regional Indian population is a question to be answered.

Objective

To assess the effectiveness of the different methods of estimating fetal weight by Johnson’s formula and Hadlock formula.

Materials and methods

With level IV evidence, a prospective observational study was performed from September 2016 to August 2018 in the department of Obstetrics and Gynaecology, Bapuji hospital, Chigateri Government General Hospital, Women and Child Health hospital attached to JJM Medical College, Davangere, Karnataka, India. The patients for this study were recruited by convenient sampling technique. A total of 200 women who satisfied the inclusion and exclusion criteria were taken for the study.

After getting IEC clearance from the institute and informed written consent from the patients enrolled in our study, they were subjected for thorough examination. Prior to allocation, participants were counselled regarding the study, and explained that ultrasound which is a routine for obstetrics cases is a non-invasive and safe procedure and consent obtained in a designated form and they were formally included in the study. The relevant parameters were recorded in a pre-designed proforma which included identification data, demographic characteristics, general physical examination and obstetrical examination.

Women with confirmed gestational age i.e. 37–42 weeks, women with high risk pregnancies, women with dating scan or with reliable date and patients who were willing to participate in the study were included in the study. Women with gestational age less than 37 weeks, women with preterm pregnancy, multiple gestations and congenital fetal anomaly and patients who were not willing to participate in the study were excluded from the study.

Procedure

The apparatus used in the set-up for ultrasonography was real time ultrasound scan, equipment Philip HD 7 with a transducer frequency of 3.5Mhz Biparietal Diameter (BPD) was measured on the frozen image from the outer edge of the proximal skull to the inner edge of the distal skull table, with electronic calipers placed on a line perpendicular to mid line echo (Figure 1). Head circumference (HC) was measured at the same section as above using ellipse method by tracing the head circumference along the outer skull table (Figure 2). Abdominal circumference (AC) was measured at the level of umbilical vein as it enters liver. Stomach bubble was also taken as landmark. It was measured using ellipse method (Figure 3). Femur Length (FL) was measured from greater trochanter to external condyle, excluding femoral head (Figure 4). Then standard tables stored in the equipment calculated the EDD. We also looked for cardiac activity, number of fetuses, congenital anomalies and placental localization and amniotic fluid index. All the ultrasonic examinations were performed by single operator who had specific training in ultrasonography. The measurements obtained using parameters viz. BPD, HC, AC, FL was entered in “Microsoft Excel” which contained Johnson’s formula and Hadlock formula and EFW was obtained.
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Figure 4 Measurement of femur length (FL).

Hadlock formula

$$\log_{10} EFW = 1.3596 - 0.00386 (AC \times FL) + 0.0064 (HC) + 0.00061 (BPD \times AC) + 0.0425 (AC) + 0.174 (FL)$$

The actual birth weight of baby recorded within 5 minutes of delivery on a mechanical scale with accuracy of ± 50 gram and the actual weight of neonate were compared to ultrasound predicted birth weight and clinical predicted birth weight.

Outcome measured

A. Actual birth weight and ultrasound predicted birth weight.
B. Actual birth weight and Johnson formula predicted birth weight.
C. Which formula is near accurate in estimating the fetal birth weight?
D. To find regional population specific mean birth weight.

Results

The analytical statistics were evaluated statistically with IBM SPSS Statistics for Windows, Version 24.0, IBM Corp, Chicago, IL. All 200 patients were subjected for statistical analysis.

The mean (±SD) age of the study population was 24.48±2.8 years. 87% (n=174) of the study population were between 20–30 years followed by 9% (n=18) below 20 years and 4% (n=8) above 30 years. The mean (±SD) weeks of gestational age of the study population was 38.90±1.25 weeks. A total of 35% (n=70) of subjects were between 39.1–40 weeks of gestation followed by 25.5% (n=51) between 38.1–39 weeks, 22% (n=44) between 37.1–38 weeks and 17.5% (n=35) between 40.1–41 weeks. Out of 200 subjects, 53.5% were primipara and 46.5% were multipara.

A total of 36.4% of subjects were between 60–70kgs of weight followed by 30.70% between 50–60kgs, 17.14% between 70–80kgs, 7.14% between 40–50kgs and 80–90kgs each and 1.42% subjects of more than 90kgs of weight. The distribution of estimated and actual birth weight was tabulated in Table 1. The majority of the birth weight were distributed between 2.5-3.5kg P value for both Hadlock formula and Johnson’s formula were 0.5 i.e. >0.05 not significant.

The mean (±SD) of birth weight using Hadlock’s formula were 3212.85±371.47 grams and Johnson’s formula was 3227.54±401.17 grams. The mean (±SD) of actual birth weight were 3025.40±445.17 grams. The mean birth weight of Hadlock formula is closest to the mean of actual birth weight. The mean error of birth weight using Hadlock’s formula was 188.44±405.51 grams and Johnson’s formula was 202.14±403.88 grams.

The primary objective of this study was to determine how accurately each of the formulae predicted the birth weight and compare them with actual birth weight. The difference between expected birth weight and actual birth weight was also noted. The percentile error of birth weight calculated from the different formulae was noted. The significance of difference between predicted and actual birth weight has been tested using statistical test of significance. The p value for both the formula were highly significant (p<0.01). The distribution of birth weight according to Hadlock’s and Johnson’s formulae was tabulated in Table 2.

Table 1 Distribution of estimated and actual birth weight

<table>
<thead>
<tr>
<th>EFW in kg</th>
<th>Hadlock formula (%)</th>
<th>Johnson's formula (%)</th>
<th>Birth weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5–2</td>
<td>3 (1.5%)</td>
<td>4 (2.0%)</td>
<td>23 (11.5%)</td>
</tr>
<tr>
<td>2–2.5</td>
<td>7 (3.5%)</td>
<td>63 (31.5%)</td>
<td>88 (44.0%)</td>
</tr>
<tr>
<td>2.5–3</td>
<td>91 (45.5%)</td>
<td>81 (40.5%)</td>
<td>64 (32.0%)</td>
</tr>
<tr>
<td>3–3.5</td>
<td>46 (23.0%)</td>
<td>42 (21.0%)</td>
<td>17 (8.5%)</td>
</tr>
<tr>
<td>&gt;4</td>
<td>10 (5.0%)</td>
<td>5 (2.5%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Distribution of birth weight according to Hadlock’s and Johnson’s formulae

<table>
<thead>
<tr>
<th>Actual birth weight (in grams)</th>
<th>Hadlock's formula</th>
<th>Mean error</th>
<th>Johnson's formula</th>
<th>Mean error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 – 2000</td>
<td>2316</td>
<td>449.33</td>
<td>2685</td>
<td>818.33</td>
</tr>
<tr>
<td>2001 – 2500</td>
<td>2949</td>
<td>545.8</td>
<td>2937</td>
<td>533.56</td>
</tr>
<tr>
<td>2501 – 3000</td>
<td>3160</td>
<td>327.67</td>
<td>3142</td>
<td>300.1</td>
</tr>
<tr>
<td>3001 – 3500</td>
<td>3306</td>
<td>23.4</td>
<td>3317</td>
<td>33.51</td>
</tr>
<tr>
<td>3501 – 4000</td>
<td>3570</td>
<td>327.5</td>
<td>3633</td>
<td>150.23</td>
</tr>
</tbody>
</table>

Discussion

Ultrasound estimation of fetal weight is utmost significance in obstetric practice. The accurate estimation of the fetal weight helps in management of preterm and small for gestational age (SGA) fetuses, where obstetrician can decide the route of delivery based on the neonatal setup available. The accurate estimation of fetal weight is utmost important in large for gestational age fetuses (Table 3).

Table 3 Comparison of different studies with the outcome

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No of subjects</td>
<td>200</td>
<td>200</td>
<td>400</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Age (years)</td>
<td>24.48</td>
<td>27</td>
<td>25.78</td>
<td>26.18</td>
<td>32.73</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>38.9</td>
<td>37–42</td>
<td>39.14</td>
<td>37–42</td>
<td>37–42</td>
</tr>
<tr>
<td>Parity</td>
<td>53.5%</td>
<td>45%</td>
<td>85.75%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scan delivery interval</td>
<td>&lt;10 days</td>
<td>&lt;7 days</td>
<td>-</td>
<td>&lt;14 days</td>
<td>&lt;7 days</td>
</tr>
<tr>
<td>Formula</td>
<td>Hadlock</td>
<td>Johnson</td>
<td>Johnson</td>
<td>Hadlock</td>
<td>Hadlock</td>
</tr>
<tr>
<td>Mean (±SD) birth weight (grams)</td>
<td>3213.85±371.47</td>
<td>3227.54±401.17</td>
<td>-</td>
<td>3318.16±351.72</td>
<td>3238±452</td>
</tr>
<tr>
<td>Mean (±SD) error (grams)</td>
<td>188.44±405.51</td>
<td>202.14±403.88</td>
<td>299.11±258.40</td>
<td>227.17±180.38</td>
<td>3318.16±351.72</td>
</tr>
<tr>
<td>LSCS</td>
<td>55%</td>
<td>30%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FTVD</td>
<td>45%</td>
<td>-</td>
<td>70%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Our objective of the present study was to compare the correlation of the Hadlock and Johnson’s formulae with actual birth weight and to find the mean birth weight of the regional population. A total of 59.5% subjects were in the age group of 20–25 years. The mean age was 24.48±2.8 years. As it was the most fertile period, more number of cases was seen. In the present study, the age group of subjects were comparable to Tiwari and Sood et al.14 and Bhandary et al.15 The age of the subject had no effect in estimating the fetal weight. 35% of the cases were in the distribution between 39–40 weeks with the mean gestational age of 38.9±1.25 weeks which was comparable to Watchree et al.16 study.

A total of 53.5% of subjects are primigravida where as in Bandari et al.17 study 45% were primigravida. Both gestational age and parity does not affect the EFW. For all the cases scan delivery interval was more than 10 days. 76.5% of birth weight was between 2.5–3.5kgs which was comparable to Bandari et al.17 study. The weight of the subjects at term was 36.4% between 60–70kg.

The mean birth weight of hadlock was closest to the mean of actual birth weight in comparis on with the Johnson’s formula. But there was no significant difference between mean of Hadlock and Johnson formulae. The mean of Hadlock was 3213.85±371.47grams which was comparable to Ayoola et al.16 study with mean birth weight of 3238±452grams. The mean weight of Johnson was 3227.54±401.1grams which was comparable to Watchree et al.15 study i.e. 3318.16±351.72grams. The p value obtained for the mean birth weight of Hadlock formula and Johnson’s formula which is <0.01. This indicates that both formulae are highly significant in obtaining the mean birth weight but not when taken individually.

The mean error of Johnson formula was 202.148grams which was in correlation with that of Watchree et al.15 and Bandari et al.16 study. But in a study of Tiwari and Sood et al.14 the mean error was more than that of our study. The mean error of the Hadlock formula was 188grams which was less than that of Bandari et al.14 and Ayoola et al.16 study.

The variation of birth weight in different weight group by different formula the number of cases of actual birth weight were grouped in groups and the expected mean birth weight of two formulae were calculated. The fetal weights were overestimated between 1.5–2.5kgs birth weight. The overestimation was more in Johnson’s formula because that was influenced by the maternal obesity and liquor volume. Between 2.5–3.5kgs estimation was in pari with actual birth weight. Again the birth weight of more than 3.5kgs, there was underestimation of the weight. According to present study, for SGA babies Hadlock formula was better and for LGA babies Johnson’s formula was a better formula. The measurement of subcutaneous tissue by ultrasound was the better method for LGA babies.

We also studied the effect of fetal weight in the mode of delivery. As there were other factors involved, such as fetal distress, liquor volume, previous LSCS, EFW alone did not affect the mode of delivery. 45% delivered vaginally and 55% underwent LSCS. As ours is a tertiary hospital % of LSCS is more.

Limitations of the study: All fetuses tend to gain some weight in utero from the day of scan till date of delivery. In one study sonographic fetal weight estimates were corrected by 12.4grams per day for female fetuses and 13grams per day for male fetuses for the period that elapsed between the performance of the obstetric ultrasonographic examination and delivery. However, in our study such a correction was not made. As present study was done in the institution with different scan machines done by different radiologists. Hence there could be inter observer errors.

Conclusion

We conclude that Johnson’s formula overestimated the weight in SGA fetuses and Hadlock formula underestimated the weight in LGA fetus. According to present study, for SGA babies Hadlock formula was better and for LGA babies Johnson’s formula was a better formula. The measurement of subcutaneous tissue by ultrasound was the better method for LGA babies. Thus ultrasound imaging can be a valid method of fetal weight estimation using the right regression equation.
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Conflicts of interest
Authors disclose no conflict of interests in publication of this study.

References